IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

KAPOK AND COTTON BLEND NON - WOVEN FABRIC

[1] Ms. P. Kavipriya, [2] Ms. C. Dhanalakshmi, [3] Mr. L. Nagarajan, [4] Dr. Mrs. C. Kayalvizhi

[1]Sencond Year Student, [2]Associate Professor, [3] Associate Professor, [4] Associate Professor
[1] Department of Textile Technology,
[1] Jaya Engineering College, Chennai, India

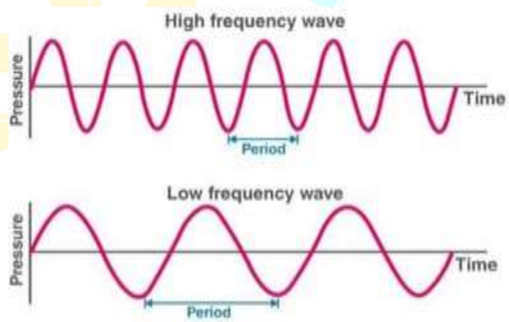
***ABSTRACT*:** In the industrialized world, noise is one of the major problems. High noise levels can cause sleep disturbances, hearing loss, decrease in learning ability and increase in stress and blood pressure. Therefore, unwanted noise must be controlled by using noise barriers or noise absorbers. Conventionally noise is controlled by using synthetic materials such as glass, polymer foams, mineral fibers and plastic materials which are expensive and non-biodegradable and cause detrimental effects to the environment. Therefore, now a day, the usage of natural materials is encouraged. In our project, we have used natural arrogate cellulosic fiber Areca, Kapok, and cotton in three different combinations (50/20/30, 50/30/20 and 30/50/20) and formed a needle punched non-woven fabric to investigate the feasibility of this material for acoustic applications. Apart from sound absorption testing, thickness and GSM were also tested. The results shows that thickness has major influence in sound absorption. The thicker the material, higher is the sound absorption. Hence, from the results, it is revealed that the material produced by using Areca, Kapok and Cotton shows better sound absorption at frequency of common audible range and this material can be used for room acoustics applications.

INTRODUCTION: The problem of noise pollution is increasing day by day around the world. Increased application of different mechanical and electrical equipment in domestic and industrial sectors has led to higher noise levels. According to the World Health Organization (WHO), the effect of noise pollution on health and environment is second to air pollution. There are some adverse effects of regular exposure to elevated noise levels to humans. High levels of noise can lead to hypertension, hearing loss, sleep disturbances, heart disease and increased stress. Unwanted sound can damage physiological and psychological health. High noise pollution can also result in cardiovascular effects. One minute exposure to sound level over 100dB noise leads to permanent hearing loss. The poor acoustical conditions in interior space can create an uncomfortable noise. It leads to fatigue, inability to concentrate, poor speech intelligibility and hearing damage. Although all materials possess some amount of sound absorption property, acoustic materials are those that can absorb most of the sound energy impinged on them. Acoustic materials can be used to control and reduce the noise levels from various sources. These materials absorb and dissipate the energy converting into heat when sound travels through them. Several materials can absorb sound energy and convert into heat. The porous materials are best suited for this purpose. The common materials used for this purpose includes fibrous structure, open cell foams, fiber glass etc., Noise reduction coefficient is commonly used to rate acoustical properties of acoustic ceiling tiles, baffles, banners, office screen and acoustic wall panels. Nonwoven materials from natural fibers are already available as products for consumer and industrial uses. A relatively newer concept is to consider natural fibers as a reinforcing material. Stringent environmental legislation, growing concern for human health, safety issues and consumer awareness has forced industries to support long term sustainable growth and develop new technology based on nonwoven material for acoustic application. Synthetic sound absorbing materials like glass fiber, polyester and polyurethane are used and these fibers are harmful to human health. There is a growing interest in using natural fibers in industrial products. The main advantages of the use of natural fibers are economical production with few requirements for equipment, low specific weight, nonabrasive to molding equipment, lesser environmental impact, carbon dioxide neutral, little energy needed for production, worldwide availability, and possible energy recovery at end-of-life Introducing the natural fiber as a sound absorbent material may reduce the sound intensity level and not harmful to human health. The natural fibers used for sound absorbent material are coir, sisal, jute, bamboo, kapok, and areca. Natural fiber reinforced materials are light in weight and possess better electrical resistance, good thermal and acoustic insulating property. The various product of sound absorption material has been commercialized in open market. Practically, these sound absorption materials are applied as interior lining for apartments, automotive, aircraft, floorings and other interior surface of the wall which helps to reduce the reverberant noise.

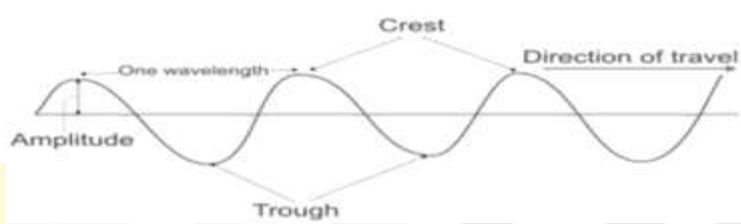
SOUND: In physics, sound is a vibration that propagates as an acoustic wave, through a transmission medium such as gas, liquid or solid. In human physiology and psychology, sound is the reception of such waves and their perception by the brain. Only acoustic waves that have frequencies lying between about 20 Hz and 20 kHz elicit an auditory percept in humans. Sound waves above 20 kHz are known as ultrasound and are not audible to humans. Sound waves below 20 Hz are known as infrasound.

PHYSICS OF SOUND: Sound can propagate through a medium such as air, water and solids as longitudinal waves and as a transverse wave in solids. The sound waves are generated by a sound source, such as the vibrating diaphragm of a stereo speaker. The sound source creates vibrations in the surrounding medium. As the source continues to vibrate the medium, the vibrations propagate away from the source at the speed of sound, thus forming the sound wave. During propagation, waves can be reflected, refracted, or attenuated by the medium.

PROPAGATION OF SOUND WAVES: Sound is transmitted through gases, plasma, and liquids as longitudinal waves, also called compression waves. It requires a medium to propagate. Through solids, however, it can be transmitted as both longitudinal waves and transverse waves. Longitudinal sound waves are waves of alternating pressure deviations from the equilibrium pressure, causing local regions of compression and rarefaction. While transverse waves (in solids) are waves of alternating shear stress at a right angle to the direction of propagation. Sound waves may be "viewed" using parabolic mirrors and objects that produce sound.

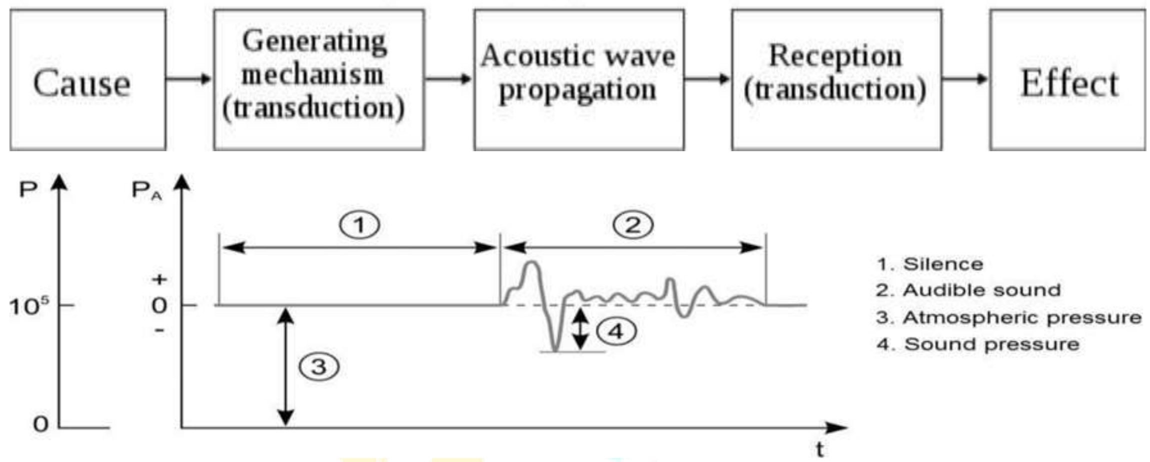


Sound wave properties and characteristics: Although there are many complexities relating to the transmission of sounds, at the point of reception (i.e. the ears), sound is readily divided into two simple elements: pressure and time. These fundamental elements form the basis of all sound waves. They can be used to describe, in absolute terms, every sound we hear.
Sound waves are often simplified to a description in terms of sinusoidal plane waves, which are characterized by these generic properties:
Frequency, or its inverse, wavelength, Amplitude, sound pressure or Intensity and Speed of sound Direction A simple wave for sound is shown in Figure 2.2. This wave can be described in terms of Amplitude, Frequency, Wavelength, Period, and Intensity.



ACOUSTICS: Acoustics is the branch of physics that deals with the study of mechanical waves in gases, liquids, and solids including topics such as vibration, sound, ultrasound and infrasound. The application of acoustics is present in almost all aspects of modern society with the most obvious being the audio and noise control industries.
The areas of acoustical studies and their applications include,
Archaeoacoustics is studied by testing the acoustic properties of prehistoric sites, including caves. **Aeroacoustics** is the study of noise generated by air movement, for instance via turbulence, and the movement of sound through the fluid air.
Architectural acoustics (also known as building acoustics) involves the scientific understanding of how to achieve good sound within a building.
Bioacoustics is the scientific study of the hearing and calls of animal calls, as well as how animals are affected by the acoustic and sounds of their habitat.

FUDAMENTAL CONCEPT OF ACOUSTICS:



Sound pressure level (SPL) or acoustic pressure level is logarithmic measure of the effective pressure of a sound relative to a reference value. Sound pressure level, denoted *Lp* and measured in dB, is defined by equation 2.1.

Lp = ln (p/p0) Np = 2 log10 (p/p0) B = = 20 log10 (p/p0) dB............................ (2.1)

Where, p is the root mean square sound pressure. p0 is the reference sound pressure.

NOISE: Noise is defined as unwanted sound. There are many cases and applications that reducing noise level is of great importance. Loss of hearing is only one of the great effects of continuous exposure to excessive noise levels. Noise can interfere with sleep and speech, and cause discomfort and other non-auditory effects. Moreover, high level noise and vibration lead to structural failures as well as reduction in life span in many industrial equipment's. Industrial machinery, air/surface transportation and construction activities are assumed to be main contributors of noise pollution.

PRINCIPLES OF NOISE CONTROL: An effective model for noise control is the source, path, and receiver model. Hazardous noise can be controlled by reducing the noise output at its source, minimizing the noise as it travels along a path to the listener, and providing equipment to the listener or receiver to attenuate the noise.

Source: A variety of measures aim to reduce hazardous noise at its source. Physical materials, such as foam, absorb sound and walls to provide a sound barrier that modifies existing systems that decrease hazardous noise at the source.

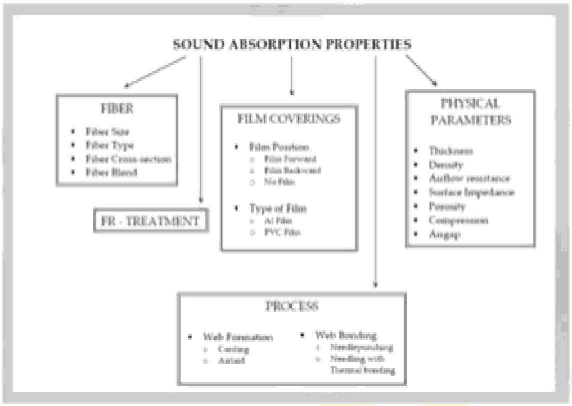
Path: The principle of noise reduction through pathway modifications applies to the alteration of direct and indirect pathways for noise. Noise that travels across reflective surfaces, such as smooth floors, can be hazardous. Pathway alterations include sound dampening enclosures for loud equipment and isolation chambers from which workers can remotely control equipment while removed from noise. These methods prevent sound from traveling along a path to the worker or other listeners.

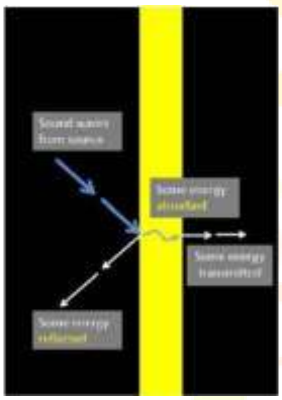
Receiver: In the industrial or commercial setting, workers must comply with the appropriate Hearing conservation program. Administrative controls, such as the restriction of personnel in noisy areas, prevents unnecessary noise exposure. Personal protective equipment such as foam ear plugs or earmuffs to attenuate sound provide a last line of defines for the listener.

MECHANISM OF SOUND ABSORPTION:

Sound absorption is an energy conversion process. The kinetic energy of the sound travels in air are converted into heat energy when it strikes the fibre surface. When a sound wave strikes any of the surfaces, some of the sound energy is reflected and some penetrates the surface. Parts of the sound wave energy are absorbed by conversion to heat energy in the material, while the rest is transmitted through. The level of energy converted to heat energy depends on the sound absorbing properties of the material

Factors affecting sound absorption of non-woven:





FIBRE PARAMETERS:

Fibre diameter: Sound absorption coefficients depend upon fibre diameter. This is because thin fibres can move more easily than thick fibres on sound waves.

Fibre surface area and cross-section: The friction between fibre and air increases with fibre surface area resulting in a higher sound absorption. Thus, the cross-section of fibre giving more surface area is preferred.

Porous fibres: Samples produced with high percentage of hollow fibres recorded the highest rate of sound absorption.

MATERIALS AND METHODOLOGY AND SELECTION OF FIBRES:

Areca, Kapok and Cotton fibres are selected for this project.

? Areca fibre is sourced from agricultural lands

? Kapok fibre is sourced from Salem local market.

? Cotton fibre is also sourced from Salem local market.

ARECA FIBRE:

Botanical name: *Areca Catechu Linnaeus*

Family: Arecaceae (Palm family) Sub family: Arecoideae

The areca fibres are extracted from the areca husk. The natural
areca fibre is inexpensive, abundantly available and a very high potential perennial crop. Betel nut fruits are divided into 3 types based on its maturity level i.e., raw, ripe, and matured fruits. The difference in physical appearance between all these 3 types of betel nut fruit is shown
in figure 3.2. The fibrous portion of the fruit consists of 2 types of fibre i.e., fine, and coarse fibres.

PROPERTIES:

(a) (b) (c)

The properties of the areca fibres are as follows,

? Areca fibre has good flexural rigidity.

? Density of the areca fibre is found to be 1.25g/cu.cm.

? These fibres are highly flexible.

? Tensile strength of the areca fibre is found to 128.79MPa.

? Tensile strength of the fibre increases as the aspect ratio increases.

FIBRE EXTRACTION: The husk covering the areca nuts are discarded after extracting the seeds. These discarded husks are
collected from the nearby area and soaked in water for 5 days. The soaked husks are cleansed with running water every day. Soaking process loosens the fibres and removes the dust particles. They are then sun dried for 3 days to reduce the moisture content and the fibres from the husk are separated by the hand. These fibres are dried and stored for further process.

DRIED

ARECA NUT
RETTING PROCESS

KAPOK FIBRE:

Botanical name: Ceiba pentandra Order: Malvales Family: Malvaceae
Kapok fibre is a natural cellulosic fibre obtained from the seeds of Kapok plant Ceiba pentandra. It is also known as silk cotton or Java cotton. It is a smooth, unicellular, cylindrically shaped and twist less fibre. Kapok fibre is a highly lignified organic seed fibre and mainly consists of cellulose, lignin and xylan.

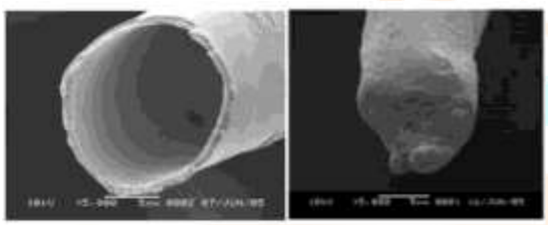
PROPERTIES OF KAPOK:

Appearance: Lustrous, yellowish brown and made of mix of lignin and cellulose.

Absorbency: The hydrophobic characteristics of kapok fibre could be attributed to its waxy surface while its large percent of lumen contributed to its oil absorbency and retention capacity.

Thermal behaviour: Heat retention of kapok was better than that of other fibres due to static immobile air held in large lumen region of kapok.

SEM Micrograph of cross section and end of kapok fibre:



BLEND RATIO: For developing the nonwoven acoustic material, the selected fibres are blended in three different ratios.

S.NO	SAMPLE	ARECA(%)	KAPOK(%)	COTTON(%)
1	Sample - A	50	20	30
2	Sample - B	50	30	20
3	Sample - C	30	50	20

WEB FORMATION: Nonwoven manufacture starts with the arrangement of fibres in a sheet or a web form. There are several ways to form the web. The fibrous web formation is done by carding. Carded web method which is also known as dry laid method which is used for the staple fibre. The fibres are blended with three different proportions and the web is formed with the help of miniature carding machine. 15 webs are formed each weighing 50g. The web is collected from the carding machine for the further process.

CARDING MACHINE SPECIFICATIONS: The webs are formed by the TRYTEX miniature carding machine with the following specifications. MACHINE MODEL: TRYTEX TYPE: Miniature microprocessor-based machine CAPACITY: 50 – 100 gms per batch LICKER-IN DIAMETER: 126 mm CYLINDER DIAMETER: 250 mm DOFFER DIAMETER: 180 mm FRONT ROLLER SPEED: 0.396 rpm CYLINDER SPEED: 851 rpm DOFFER SPEED: 4.5 rpm DELIVERY SPEED: 2.5434 m/min

NEEDLE PUNCHING PROCESS: Needle punching is a web bonding technique in which the fibres are mechanically entangled to produce a nonwoven fabric by repeated penetration of barbed needles through a preformed dry fibrous web. This is done in a machine called needle loom. The fibrous web which is made from the card has been fed into the machine feed rollers. Two of the webs are led in such a way that one web is laid over the other in a parallel manner. The needles in the machine are arranged in a needle board in the width wise rows. The needle mounted on the needle board will move up and down reciprocating motion byeccentric crank mechanism. During down stroke the needles descend through the web. As a result, the fibres are mechanically interlocked, thereby providing the mechanical strength. The nonwoven is delivered by the delivery rollers. No. Of needles – 1320 Type of needle - Barb needle Feed rate(mm/stroke) - 10 mm/stroke No. of punches per minute - 40 punches

SOUND ABSORPTION TEST: The sound absorption property is measured by reverberation time method with the specification of ASTM C-423. The acoustic characterisation of the samples is tested at PHASE ACOUSTICS, Coimbatore. The experimental setup is shown in fig-3.11. We used a loudspeaker system, a microphone for generating sound signal, a sound pressure level meter, and a reverberation room chamber of volume 64 cubic feet. The testing is carried out under two conditions-without sample (empty room absorption) and with samples (full room absorption). First, the reverberation time of the empty room without samples is measured by the following procedure. A band of random pink noise, a 1/3 octave band noise at 90 dB, was used as a test signal and was turned on long enough for the sound signal to stabilize. When the signal was turned off, the sound pressure level decreased (90-60=30dB) and each frequency band's decay rate was determined by measuring the slope of a straight line fitted to the average decay curve's sound pressure level.The absorption of the empty room was calculated from the

Sabine absorption formula, $A = 0.92\ VD/C$ ....

where A is the sound absorption (m2 or Sab) V is the volume of reverberation room (m3)

C is the speed of sound =343 m/s;

D is the decay rate (dB/s).

The specimen of size 18 x 18 inches (Areca,kapok,cotton blended nonwoven) was installed and the same procedure is repeated for measuring full room absorption. The specimen's absorption coefficients were calculated as follows:

$\alpha = (A2 - A1)/S$.................(Equation 3.2)

where A2 is the absorption of the room after the specimen has been installed (m2 or Sab) A1 is the absorption of the empty reverberation room (m2 or Sab)

S is the total overall area of the specimen (m2)

By this method, the sound absorption of the produced three samples were tested.

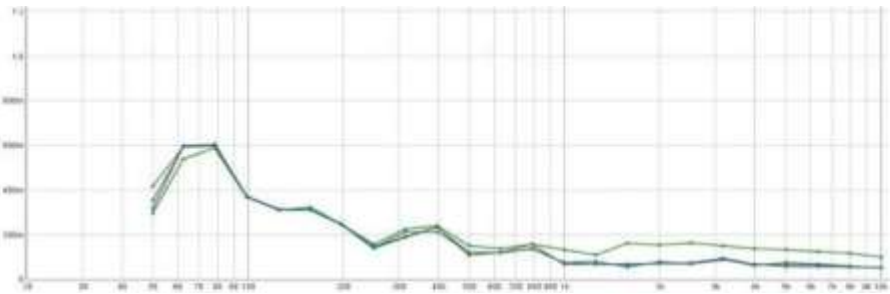
NOISE REDUCTION COEFFICIENT (NRC): The Noise Reduction Coefficient (NRC) is a scalar representation of the amount of sound energy absorbed upon striking a particular surface. An NRC of 0 indicates perfect reflection; an NRC of 1 indicates perfect absorption. In particular, it is the average of four sound absorption coefficients of the particular surface at frequencies of 250 Hz, 500 Hz, 1000 Hz, and 2000 Hz. These frequencies encompass the fundamental frequencies and first few overtones of typical human speech, and therefore, the NRC provides a decent and simple quantification of how well the surface will absorb the human voice. A broader frequency range should be considered for applications such as music or controlling mechanical noise. Specifications for materials used in sound absorption commonly include an NRC for simplicity, in addition frequency vs amplitude charts.

SOUND ABSORPTION AVERAGE (SAA): The single number rating obtained from ASTM C423 is the Sound Absorption Average (SAA). This is the average of the absorption coefficients for the twelve one-third octave bands from 200 to 2500 Hz. The SAA supersedes the Noise Reduction Coefficient (NRC), which is the average of the sound absorption coefficients of a test specimen for 250, 500, 1000 and 2000 Hz rounded to the nearest multiple of 0.05. The higher the SAA or the NRC value, the better the material absorbs sound. The Noise Reduction Coefficient (NRC) and Sound Absorption Average (SAA) values are both single number ratings that indicate the level of sound absorption provided by the product being tested. The NRC value is rounded off the nearest 0.05 increment. The SAA value is rounded off the nearest 0.01 increment. The NRC and SAA values normally range from 0.00 to 1.00, with 1.00 indicating 100% sound absorption per square foot of material. These values can exceed 1.00 when thick specimens or specimens with large air spaces are being tested.

MOISTURE CONTENT TESTING: The moisture content of the produced nonwoven was tested by Oven-dry method. The oven-dry method adopts a system consisting mainly of a 40 forced air-drying chamber and a weighing device having a minimum sensitivity equal to ± 0.05% of the weight of the sample. By positioning the sample of known weight in this chamber, at a drying temperature equal to 105 ± 2˚C, it is dried until when the difference of weight between the results of two subsequent weighing, performed at a few minutes interval, is not higher than 0.05% of the sample dry weight. By comparing the weight of the sample before and after drying, the moisture content absorbed by the fibre material.

RESULTS AND DISCUSSION: This chapter describes the sound absorption properties of nonwoven materials developed in this project. Three samples with varying proportions of Areca, Kapok and Cotton namely 50/20/30 and 50/30/20 and 30/50/20 were produced and evaluated. The following section discusses the results obtained. The sample pictures are shown in the figure

SOUND ABSORPTION TEST:



Sample A
Areca - 50
Kapok - 20
Cotton - 30
Thickness -6.92 mm
GSM - 6.70

Fig-4.1 Sample A

Sample B
Areca - 50
Kapok - 30
Cotton - 20
Thickness -7.29 mm
GSM -7.01

Fig-4.2 Sample B

Sample C
Areca - 30
Kapok - 50
Cotton - 20
Thickness -7.52 mm
GSM -8.05

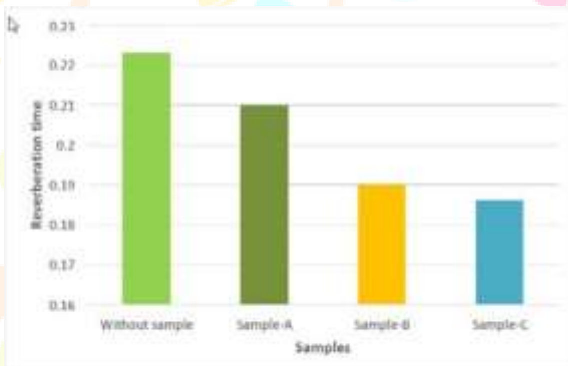
Fig-4.3 Sample C

The reverberation time of the samples were calculated from low to high frequency range. The results are shown in

S.no	SAMPLE	BLEND RATIO (Areca:Kapok:Cotton)	REVERBERATION TIME(sec)
1	Without sample	-----	0.223
2	Sample - A	50:20:30	0.210
3	Sample - B	50:30:20	0.190
4	Sample - C	30:50:20	0.186

Reverberation time of the samples

Comparison of reverberation time of the samples
Light green - without specimen- sound reached at 0.223 sec
Dark green - Sample-A - sound reached at
0.210 sec



Orange - Sample-B - sound reached at 0.190 sec
Blue - Sample-C - sound reached at 0.186 sec

The test results clearly depict that increase in Kapok proportion with respect to Areca in the blend shows better sound absorption.

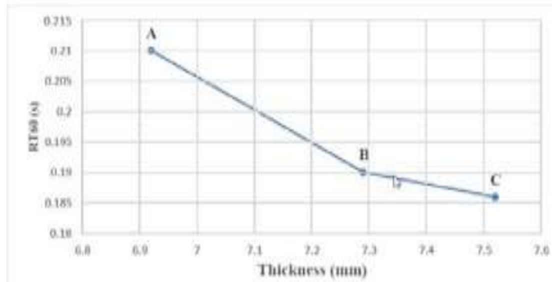
MOISTURE CONTENT TEST: The moisture content test was carried out by Oven-dry method and the results are shown in the results shows that the blend with least Kapok content have low moisture content than the other blends.

S.no	SAMPLE	BLEND RATIO Areca:Kapok:Cotton	INITIAL WEIGHT	DRY WEIGHT	MOISTURE CONTENT
1	Sample - A	50:20:30	14 g	13.45 g	3.93%
2	Sample - B	50:30:20	19.97 g	18.5 g	7.36%
3	Sample - C	30:50:20	22.68 g	21.23 g	6.39%

RELATION BETWEEN THICKNESS AND SOUND ABSORPTION: From the tested results, it has been found that the Thickness and area density play a major role in sound absorption. Thickness has a greater influence in sound absorption because as the thickness of the material increases, the area density also gets increased. Thickness and Area density of the samples

S.no	SAMPLE (A:K:C)	THICKNESS (mm)	GSM	RT_{60} (sec)
1	Sample - A (50:20:30)	6.92	6.7	0.210
2	Sample - B (50:30:20)	7.29	7.01	0.190
3	Sample - C (30:50:20)	7.52	8.05	0.186

Thickness and GSM of the samples



Variation of RT60 with respect Thickness

From the results, as thickness increases, the Reverberation time decreases, which means that the sound absorption increases with thickness.

CONCLUSION AND RECOMMENDATIONS:

CONCLUSION: In this project, the sound absorption property of Areca, Kapok and Cotton blend nonwoven fabric was investigated. From the results, it is concluded that, the blend with higher Kapok proportion will provide better sound absorption. Considering the cheapness and abundant availability of the agro-waste Areca fibre in India, we suggest that Areca fibre can be blended with Kapok fibre and effectively used as acoustic damping material. However, further trials are necessary to conform and optimize product parameters such as blend proportion, thickness of batt, basis weight of the material and other properties.

RECOMMENDATIONS: We suggests that the Areca - Kapok- Cotton blended nonwoven can be used for room acoustics purpose as it is eco-friendly, cheaper, and abundantly available. We recommend that research may be extended by,

? Varying thickness of nonwoven batt
? Optimizing blend proportion
? Examining other sound frequencies
? Large scale technique in real life application
? Investigating the influence of other properties of the nonwoven on sound absorption behaviour to extend the use of this blended nonwoven in industrial applications.

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